LIQUID CRYSTAL DISPLAY DEVICE

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application is a divisional application of U.S. application Ser. No. 10/438,101, filed May 15, 2003, the contents of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0002] The present invention relates to a liquid crystal display device; and, more particularly, to a so-called vertical orientation type liquid crystal display device.

[0003] A liquid crystal display device is configured such that the optical transmissivity of a liquid crystal material in each pixel region is controlled in response to an electric field which is generated between a pair of electrodes and is applied to the liquid crystal material.

[0004] In such a liquid crystal display device, orientation films are arranged so as to be directly brought into contact with the liquid crystal material, thereby to determine the initial orientation direction of the liquid crystal when an electric field is not applied to the liquid crystal.

[0005] Further, although the orientation films conventionally require orientation treatment by rubbing, there is a liquid crystal mode which requires no rubbing treatment and can omit step for such a treatment, and a so-called vertical orientation type liquid crystal display device has been developed (see Japanese Patent Laid Open 11-72793, 11-109355, 11-352489, for example) on the basis of such a liquid crystal mode.

[0006] That is, with the use of so-called vertical orientation films, without use of rubbing treatment, liquid crystal molecules are arranged in the vertical direction with respect to the substrates when no electric field is applied to the liquid crystal material, and these molecules are tilted down in a plurality of directions when an electric field is applied to the liquid crystal material.

[0007] Here, due to such tilting-down of the liquid crystal molecules in a plurality of directions, the vertical orientation type of device has a feature in that a broad viewing angle can be simultaneously achieved as part of the liquid crystal display characteristics.

SUMMARY OF THE INVENTION

[0008] However, in a liquid crystal display device of the type described above, as a result of further extensive studies made by the inventors of the present invention, as shown in **FIG. 22A** to **FIG. 22C**, it has been found that, when a pressure is applied to a liquid crystal display panel LPNL from the outside, for example, when a user lightly pushes on a liquid crystal display part AR thereof with his finger, a trace corresponding to the pushed portion remains for a long time spanning about several tens of minutes per one pushing operation (the trace which remains in this manner will be referred to as a "dark spot" in this specification for convenience sake).

[0009] Such an operation to push the liquid crystal display panel LPNL is frequently performed when a discussion is being carried out among a plurality of people, while watching a display produced on the liquid crystal display panel LPNL, or when a liquid crystal display part AR of the liquid crystal display part LPNL is wiped or the like, for example. Accordingly, the fact that the trace remains in the above-mentioned manner creates a serious drawback in the practical use of the display device. This is because the liquid crystal display panel LPNL cannot produce a normal display at the location of the trace remaining portion of the display device.

[0010] As can be understood from respective manipulations shown in **FIG. 22A**, **FIG. 22B**, **FIG. 22C**, the occurrence of the trace is apparent. That is, the trace which is produced by pushing with a finger remains as it is, and when the liquid crystal display panel LPNL is pushed while moving the finger along a path having the shape of a letter or a figure, for example, the trace remains over a long time. Here, **FIG. 22A** shows a state in which a display screen of the liquid crystal display panel is not pushed; **FIG. 22B** shows a state in which the finger is moved while pushing the display screen; and **FIG. 22C** shows a state in which a trace remains after the finger is moved away from the display screen.

[0011] To explain the reasons why such a phenomenon occurs, while focusing on the behavior of the liquid crystal material, first of all, as shown in **FIG. 23A** to **FIG. 23C**, by giving the directivity to the direction of an electric field E generated between a pair of electrodes PX, CT that are respectively formed on respective substrate sides at a partial region (center in the drawing), the direction in which the liquid crystal molecules are tilted involves a plurality of directions.

[0012] Then, when the electric field E is increased sequentially in the order of **FIG. 23A**, **FIG. 23B** and **FIG. 23C** (changing a voltage applied to a pair of electrodes in the order of small→medium→large), the liquid crystal molecules LC are tilted down in two directions at a center portion, and the liquid crystal molecules LC arranged outside the center portion are tilted down in the same directions based on the tilting directions of the liquid crystal molecules LC in the center portion.

[0013] Further, as shown in **FIG. 24A** to **FIG. 24C**, when one substrate in an intermediate state (**FIG. 24A**) is pushed (**FIG. 24B**), the distance between the substrate SUB**1** and the substrate SUB**2** is narrowed (d**2**<d**1**); and, hence, the distance between the pixel electrode PX and the counter electrode CT is narrowed.

[0014] This implies that the intensity of the electric field E between the pixel electrode PX and the counter electrode CT is increased so that the liquid crystal molecules are pushed to each other, whereby an electric field stronger than a display electric field corresponding to an original gray scale is applied.

[0015] As a result, it is recognized that an intermediate layer MIDL, which is formed of liquid crystal molecules arranged substantially horizontally, is formed in the vicinity of the center of the liquid crystal layer between the substrates.

[0016] Since the liquid crystal molecules are arranged substantially horizontally relative to each other in this intermediate layer MIDL, the long axis directions of the liquid crystal molecules are juxtaposed, whereby a strong intermolecular force acts between the liquid crystal molecules.